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Water Quality Analysis by Multivariate Statistical Analysis in Gazipur Industrial Area, Bangladesh

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ABSTRACT :*In the study, selected statistical methods (Descriptive Analysis, Pearson Correlation Matrix Analysis, Cluster Analysis and Principal Component Analysis) were used to determine the surface water quality of Gazipur district area. For this purpose, a total of 20 samples has been collected from different water bodies adjacent to industrial units and pH, Temperature, DO, EC, TDS, Cu, Cd, Ni, Zn, Pb concentrations were determined in each sample. Statistical Analysis revealed that physico-chemical parameters exceeded DoE standardin all samples except Cu and Zn. Pearson Correlation matrix explicit significant positive correlation with Electrical Conductivity and Total Dissolved Solid and Cu with Electrical Conductivity, Total Dissolved Solid. Hierarchical Cluster Analysis showed two clusters indicate similar characteristics of elements. Principal Component analysis extracted three major components: PC1 denotes for EC, TDS, Pb, Cu which indicate industrial sources, PC2 is associated with Cd which is also accumulate from industrial sources and PC3 with contribution of Temperature andPb.*

KEYWORDS:*Statistical Analysis; Pearson Correlation Matrix; Cluster Analysis; Principal Component Analysis*

I. INTRODUCTION

Water is the most valuable and vital resource for sustenance of life and also for any kinds of developmental activity Kumar et al.(2010). Surface water quality is being deteriorated severely in Gazipur industrial area due to uncontrolled use in industries; industrial effluents are discharged without or with little treatment. Industrial pollution is one of the major problems that Bangladesh facing to a greater extent. Industrial sector is one of the largest water users and polluters in Bangladesh specially in industrial zoneNemerow (1978).The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, in addition to nonpoint sources such as soluble salts (natural and artificial), use of agrochemicals (fertilizers and pesticides), disposal of industrial and municipal wastewater in agriculture and others (Nriagu and Pacyna, 1998; Schalscha and Ahumada, 1998; McGrath et al., 2001; Zakir et al., 2008). The major polluting industries like textile and dyeing, paper industries, food processing industries, paints, tanneries, oil refineries, chemical complexes, fish processing units, fertilizer factories, cement factories, soap and detergent factories including light industrial units of Bangladesh discharge directly untreated or partially treated toxic effluents in the rivers Jolly (2011).Water bodies are choked with industrial effluents and untreated sewage through numerous sources which are connected with pollution sources Khan(1999). The concerns over surface water quality of the Gazipur district are gradually outbound due to the disposed location of industrial units, and the adverse effects on surrounding land and aquatic ecosystem, as well as subsequent and potential impacts on the livelihood system of the local community (Zakir et al.,2008, Rahman et al., 2011, Islam et al., 2011). The decreasing quality of water interferes with the aesthetic and economic importance of water bodies by affecting fish and other aquatic environmentIslam et al.(2009). Metals, especially 'toxic trace metals', are among the most common environmental pollutants, and their occurrence are mostly from anthropogenic sources used in different process industries and small portion from natural sources which impose deadly impacts on biotaHussain and Ahmed (1997). The presence of concentrated levels of trace metal ions in the aquatic environment results in the elevation of water electrical conductivity (EC) and Total dissolved solid (TDS) content if pH conditions is lower, but if pH is higher than Department of Environment (DoE) standard, most trace metal ions are precipitated or adsorbed onto the sediment surface. EC and TDS are very significant water quality indicators because in case of higher

level of EC and TDS different ions are increased in concentration; thus osmotic pressure changes render the water risky for the aquatic biotaMowka (1988). Different studies demonstrated clear relationship with the water quality and public health which is an issue to be concerned recently due to the emergence of new types of diseases regularly. The main objective of the study is to measure the actual surface water quality regarding physical, chemical and trace elements concentrations of Gazipur industrial area where effluents are released regularly from variety of industries and then analyzing the data using multivariate statistical tool for illustrating pollution scenario.

II. STUDY AREA

Gazipur District is located at north of capital city of Dhaka, Bangladesh. It is occurring between 23˚53' to 24˚20' North latitudes and between 90˚09' to 90˚42' east longitude. The total area of the district is 1806.36 sq. km of which 17.53 sq. km was riverine and 273.42 sq.km.is forest area District Statistics Gazipur(2011). The study area is belongsto the 'Madhupur Tract' at the northern part of Dhaka, which is slightly elevated terrace like topography. The area is occurring in between the Barhmaputra and Meghna floodplains which are elevated in between 3 m and 10 m above sea level. The soil is light to medium grey, fine sandy to clayey silt. Soils are poorly stratified and composed by alluvium soil of the Pleistocene period. Most of the low lying areas are flooded annually. Stratigraphic units exhibit iron and manganese rich deposits which are oxidized Khan et al. (2011).

Study areas were selected around the Gazipur, Bangladesh Small Cottage and Industrial Corporation (BSCIC), Tongi industrial area because most of the industrial pollution has been occurred around these areas. Most of the samples locations (Table 1) were selected nearby of the industrial units of study area.

Table (1): Sampling Locations of the study

Sample ID	Name of the area	Lattitude (dd-mm-ss)	Longitude (dd-mm-ss)
S-1	kodda, Kalakor	23 58 36.8 N	90 20 36.2 E
S-2	kalakor,turag river	23 58 49.1 N	90 20 23.5 E
S-3	kalakor, Basan	23 59 59.9 N	90 19 57.3 E
S-4	Darun Bazar, Basan	23 59 40 N	90 19 36.4 E
S-5	Darun Bazar, Turag river	23 59 34 N	90 18 32 E
S-6	Mazipara, Turag river	23 59 15 N	90 17 41 E
S-7	Hankata, Chilai river	24 00 22.6 N	90 26 37.6 E
S-8	Sosan Bridge, Burulia	24 00 35.6 N	90 25 50 E
S-9	Mirashpara, Turag Bandar	23 53 18 N	90 24 51 E
S-10	Mirashpara, Turag Bandar	23 53 10 N	90 24 49 E
S-11	Turag Bandar	23 53 01 N	90 24 47 E
S-12	Pagar, BSCIC	23 53 53.8 N	90 26 6.5 E
S-13	Near Zaber and Zubaer, BSCIC	23 53 27.8 N	90 25 14.7 E
S-14	BSCIC	23 52 26 N	90 25 14 E
S-15	Near Turag Bridge	23 53 40 N	90 23 21.9 E
S-16	Kathaldia, Baradewra, Tongi	23 53 54.5 N	90 23 07.5 E
S-17	Prottasha Bridge, Tongi	23 53 53.4 N	90 22 38.9 E
S-18	Near East West Medical College and Hospital	23 53 41.9 N	90 22 33.5 E
S-19	Dhour Bus Stop	23 53 37.4 N	90 21 56.5 E
S-20	Near AnnonTex group, Ashulia, Beribadh	23 53 20.5 N	90 21 47.3 E

III. METHODOLOGY:

3.1 Water Sampling:

Total 20 samples were collected from the surface water bodies including Turag River during pre- monsoon in 2015. Sampling depth was fixed at 2.5 ft for avoiding the surface interference Khabir et al. (2012).The sampling was done very carefully by following spot sampling techniques Gupta (2005). The high density PVC bottles were used for sampling purpose. The bottles were cleaned properly by deionized water and then with diluted HNO3 acid for avoiding any contamination with collected sample. Samples were collected randomly and sample locations were determined by hand GPS (model no-GPS map 62 GARMIN). Sample location, number and characteristics were marked on the bottles with markers for further identification. Sampling point'ssimu et al. (2017)are shown in Figure 1:

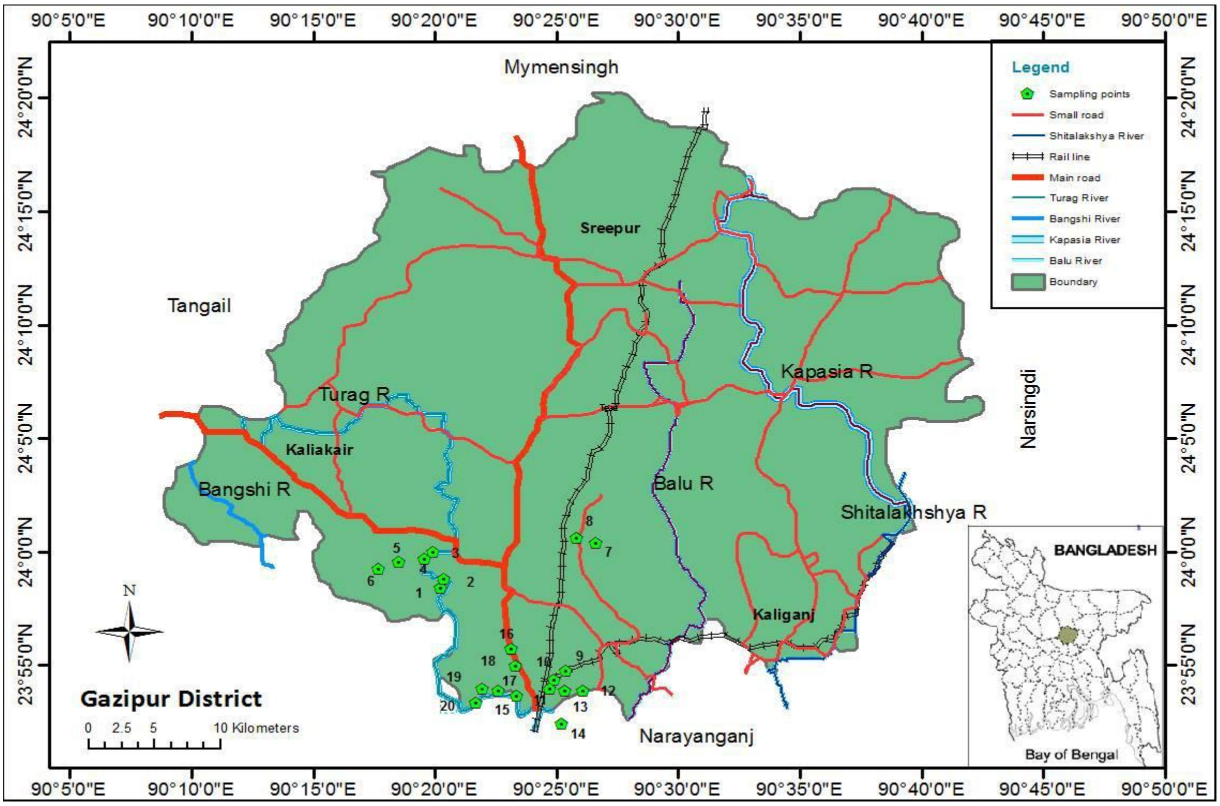

Figure 1: Location of study area and sampling sites

3.2 Physical and chemical analysis:

Water quality parameters including temperature, electrical conductivity (EC), pH, total dissolved solid (TDS), dissolved oxygen (DO) and trace elements Pb, Cu, Cd, Ni, Zn were analyzed.

The pH was determined by digital pH meter (HANNA Instrument 211, Microprocessor pH). Total dissolved solids and electrical conductivity were determined by digital TDS meter and EC meter (HM digital)(Table 2).

Temperature was determined by Thermometer and Dissolved oxygen was determined by DO meter. Trace elements were determined by Shimadzu Model AA- 7000 F PC Controlled Atomic Absorption Spectrophotometer (Table 3).

3.3 Statistical analysis:

Multivariate statistical analysis was determined by SPSS (Statistical Package for Social Science) and Microsoft Excel.Cluster analysis, a multivariate statistical technique, has been widely used to interpret complex data and to identify sources of pollution. The main purpose of cluster analysis is to split a number of variables/samples into groups that have similar characteristics, behavior or may come from same sources Mihailovic et al. (2014). Pearson correlation coefficient is commonly used to measure and establish the strength of a linear relationship between two variables or two sets of data. It is a simplified statistical tool to show the degree of dependency of one variable on the other Belkhiri et al. (2010).

Principal component analysis is used to reduce the dimensionality of a dataset, while retaining as much of the original information as possible (Jolliffe1986;

Rencher 1995). The first principal component (PC1) has the largest variance and accounts the greatest amount of the total variance. The second principal component (PC2) has the second largest variance and contributes the greatest amount of the residual variance, and so on. The scree plot is used for examining the classification of the data. The loading plot is used for investigating the importance of variable to each component Panishkan et al. (2010).

IV. RESULT AND DISCUSSION:

4.1 Physicochemical characteristics:

The physicochemical quality of collected surface water samples were characterized by blackish color and high concentrations of pH, EC, TDS and lower DO level. DO levelsranged from 2.02- 3.79 mg/L, which is lower than DoE (Department of Environment) standard. Unfortunately, all samples contained very low DO levels. This low level of DO in the water bodies has occurred probably due to the release of easily oxidized industrial organic wastes(Emongor et al. 2005); and high oxygen demanding dyes that were from different point and non-point sources Rahman and Bakri 2010).Deficiency of DO in water gives rise to odoriferous products of anaerobic decomposition Ahsan et al. (2012). Allof the samples showed temperature ranging between 32.1-34.2 ^oC with low variations which is harmful for aquatic environment. It is reported that high temperature suppresses benthic organism growth, thus poses threat on ecosystem. The pH of the collected samples ranged from 3.27-5.73 which is acidic in nature. Acidic water can dissociate trace elements which are taken and accumulated in tissues easily by living biota is detrimental to aquatic flora and fauna.Electrical Conductivity (EC) ranged from 3.27-5.73 dS/m where the highest value exhibited by sample no 6which is higher than DoEstandard 0.35 dS/m. Higher EC indicates greater discharge of ionic components from different industrial effluents.Most of the industries discharge effluents containing higher amounts of Total Dissolved Solids (TDS). Higher TDS value increases water density; reduces oxygen solubility in water and utility of water for potable and non-potable purpose Khabir et al. (2012). The physicochemical parameters are shown inTable 2.

Table (2): Descriptive analyses of physicochemical parameters

Sample no	D.O (mg/L)	pH	EC(dS/m)	TDS(mg/L)	Temperature(^0C)
S-1	3.4	4.98	1.36	4159	33.6
S-2	2.96	5.03	1.28	4862	32.4
S-3	2.32	3.5	2.54	5643	33.8
S-4	2.52	3.27	1.8	4850	32.8
S-5	2.85	5.73	1.7	4974	33.2
S-6	3.68	3.51	3.41	5181	33.2
S-7	3.79	5.02	3.02	5935	32.4
S-8	3.35	5.05	2.5	5155	32.8
S-9	3.48	3.48	1.28	4521	32.4
S-10	2.62	3.34	1.33	5847	32.7
S-11	2.74	4.09	1.9	5824	32.4
S-12	2.28	4.28	1.12	4770	32.1
S-13	2.02	5.07	2.1	4945	32.4
S-14	3.57	4.98	2.02	5859	32.5
S-15	2.97	5.42	1.6	5673	32.6
S-16	2.37	4.6	1.8	5100	33.4

S-17	3.1	4.68	1.3	5765	32.9
S-18	3.05	4.93	1.2	4800	33.3
S-19	2.24	4.66	2.1	6250	33.2
S-20	3.15	4.22	1.9	5879	34.2
Min	2.02	3.27	1.12	4159	32.1
Max	3.79	5.73	3.41	6250	34.2
Avg.	2.923	4.492	1.863	5299.6	32.915
Std.Dev.	0.5243	0.740	0.622	568.547	0.555
Standard value	4.5-8	6.5-8.5	0.35	1000	20-30

4.2 Heavy Metal concentrations:

Samples showed fluctuation in heavy metals concentration levels. The mean concentration of different metals were found in the order Pb>Zn>Ni>Cu>Cd in surface water. Heavy metals concentration is shown in Table 3.

Table (3): Descriptive analyses of heavy metals

Sample no	Pb(mg/L)	Cu(mg/L)	Cd(mg/L)	Ni(mg/L)	Zn(mg/L)
S-1	1.28	0.02	0.057	0.054	2.32
S-2	1.33	0.03	0.027	1.012	3.37
S-3	3.39	0.06	0.029	0.029	3.11
S-4	1.39	0.08	0.029	0.18	3.13
S-5	2.48	0.07	0.039	0.03	2.28
S-6	2.52	0.035	0.013	0.35	3.24
S-7	1.56	0.06	0.011	0.06	3.17
S-8	2.83	0.06	0.021	0.04	3.09
S-9	2.49	0.09	0.023	0.09	3.19
S-10	3.54	0.07	0.017	0.18	3.18
S-11	2.04	0.08	0.013	0.04	3.18
S-12	2.03	0.05	0.015	0.05	3.18
S-13	3.08	0.06	0.014	0.05	3.21
S-14	3.08	0.06	0.014	0.11	3.10
S-15	2.05	0.14	0.016	0.05	3.10
S-16	2.09	0.05	0.012	0.05	3.17
S-17	3.03	0.10	0.013	0.06	3.24
S-18	3.08	0.06	0.014	0.25	3.15
S-19	3.05	0.04	0.016	0.07	3.09
S-20	2.16	0.09	0.014	0.32	3.20
Min	1.29	0.019	0.011	0.03	2.28
Max	3.54	0.143	0.06	1.01	3.37
Avg.	2.43	0.07	0.02	0.15	3.09
Std.Dev.	0.701	0.0273	0.0115	0.229	0.276
Standard value	0.05	1	0.005	0.1	5

Among the 20 water samples Pb is found the most abundant metal among the other trace elements.Lead concentrations ranged from 1.29-3.54 ppm with average value 2.43 ppm which is much higher than DoE standard value (0.05 ppm). Sample no. 10 showed highest concentration of Lead among all the collected samples.Lead (Pb) metal compounds,metal complexes and metal alloys are used in the manufacturingof machines, catalysts, pigments, preservatives,rolled extrusions,electrolytes, protective coatings, decorative finishingagent, mordent in dyeing and printing, as a corrosionresistance, pharmaceutical industries, pyrotechnics, manufacture ofspecial glass and color picture tubes, etcSharma et al.(2006) and multi-industrialactivities.Surprisingly, Lead concentration is posing threat to living biota.Clinical signs and symptoms of lead poisoning and possibly acute encephalopathy may be present. Early symptoms of lead poisoning include abdominal pain and constipation. Acute lead encephalopathy is characterized by irritability, lethargy, coma, seizures, and in some cases, death (Chisolm and Harrison 1957;Chisolm1968). From the analysis, it is delectable that Copper is within standard limit of DoE. Copper is widely used as fertilizer in the majority of areas. Most of the areasare occupied by pharmaceutical industries, steel and other alloy production, steel plating, and textiles industries in optimum quantity.The copper (Cu) content in the surface water examined ranged from 0.019 to 0.142 mg/Lwith an average of 0.066 mg/ L lower than the DoE standard value (1 mg/L).The average concentration of Cd in the water samples was 0.02 mg/l in the sample area. According to DoE (2003), Cd must be remained within 0.005 mg/l for inland surface water. Environmental levels are greatly enhanced by industrial operations as Cd is commonly used as a pigment in paint, plastics, waste incinerationceramics, Sludgebased Fertilizers (Davis 1984) and phosphate fertilizers(MalysowaandPatorczyk 1988)and glass manufacture (Nriagu et al. 1988;Cleverly et al. 1988). Cd is a very toxic element even at very low concentrations and chronic exposure to this metal can lead to anemia, anosmia, cardiovascular diseases, renal problems and hypertension (Mielke et al., 1991;Robards andWorsfold 1991; Sharma et al.2006).The sources of Zn concentration of water in industrial locations are usually anthropogenic and not natural (Aswathanarayana1995; Romic and Romic 2003; SEGH 2001). The average Zn concentration in the study area was 3.09 mg/l in collected samples, which was within acceptable limit for inland surface water and irrigation water standards (DoE). The observed Zn concentration in surface water in collected samples probably comes from construction materials as Zn alloys, protective and coating for iron and steel. Zn is also used in pigment and reducing agent, in dry cell batteries, cotton processing, rubber industry, glass, enamels, plastics, lubricants, cosmetics, pharmaceutical, agent for burns and ointments Ahmed et al. (2011).

A Dendrogram of the variables resulting from cluster analysis is presented in Figure.2. Dendrogram showed that all variables can be grouped into two main clusters (groups). Cluster 1 involves most of the variables Cu, Cd, Ni, Pb, Zn, Dissolved Oxygen,pH, Temperature, which means they are closely related in case of source. Cluster 2 involves EC and TDS which means they came from common sources.

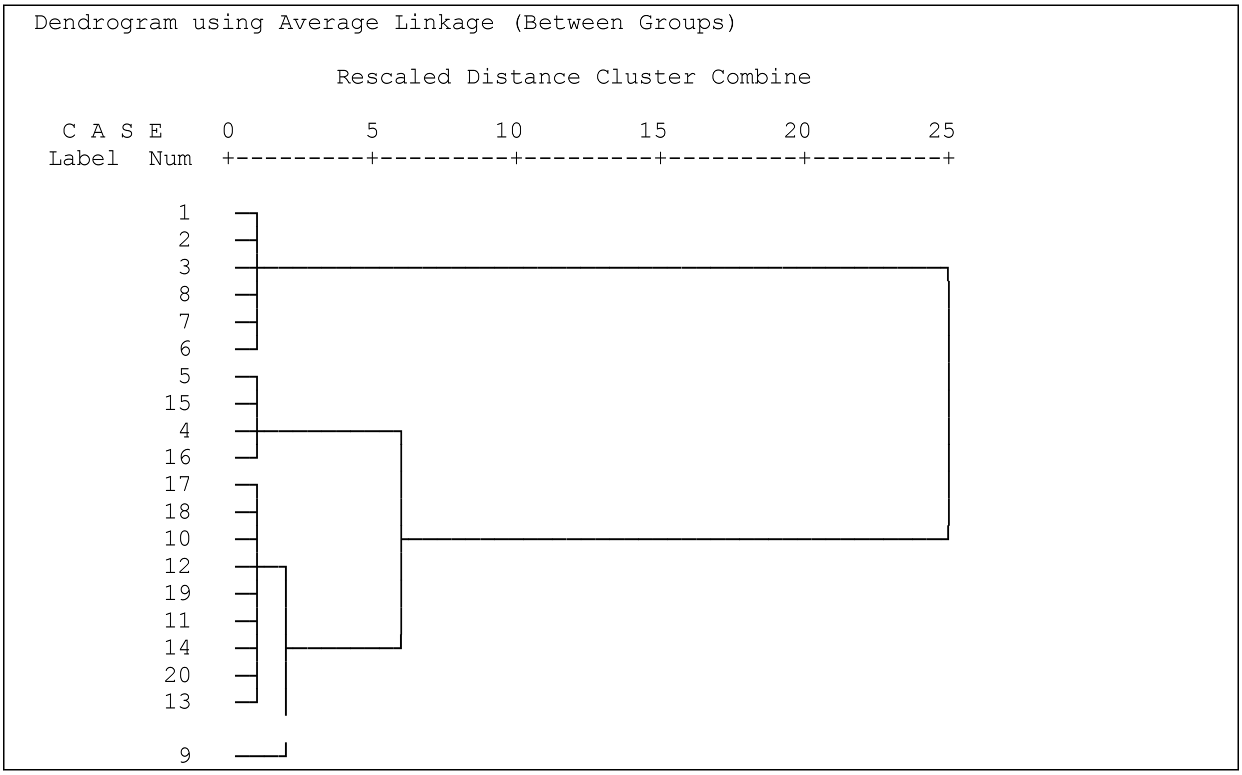

Figure 2: Dendrogram showing spatial similarities of variables produced by cluster analysis

Pearson correlation shows (Table 4) significant correlation between TDS and EC. TDS means any minerals, salts, metals, cations or anions dissolved in water. EC is the ability of water to conduct electricity through it and it depends on the dissolved ion, so there is strong possibility that they came from same sources.

Table (4): Pearson Correlation Matrix

	D.O	pH	EC	TDS	Temp.	Pb	Cu	Cd	Ni	Zn
D.O	1									
pH	.112	1								
EC	-.677**	-.013	1							
TDS	-.708**	.094	**.902****	1						
Temp.	.185	-.086	-.086	-.038	1					
Pb	-.299	-.134	.127	.226	.121	1				
Cu	-.407	.001	**.570****	**.451***	-.115	.145	1			
Cd	.203	.115	-.252	-.356	.301	-.350	-.327	1		
Ni	.241	-.018	-.336	-.296	-.035	-.313	-.310	.027	1	
Zn	.067	-.393	-.028	.016	-.326	.173	.179	-.795**	.342	1

The PCs(Figure 3) are then ordered such that the first few PCs retain most of the variation present in all of the original variables (Joliffe 1986).

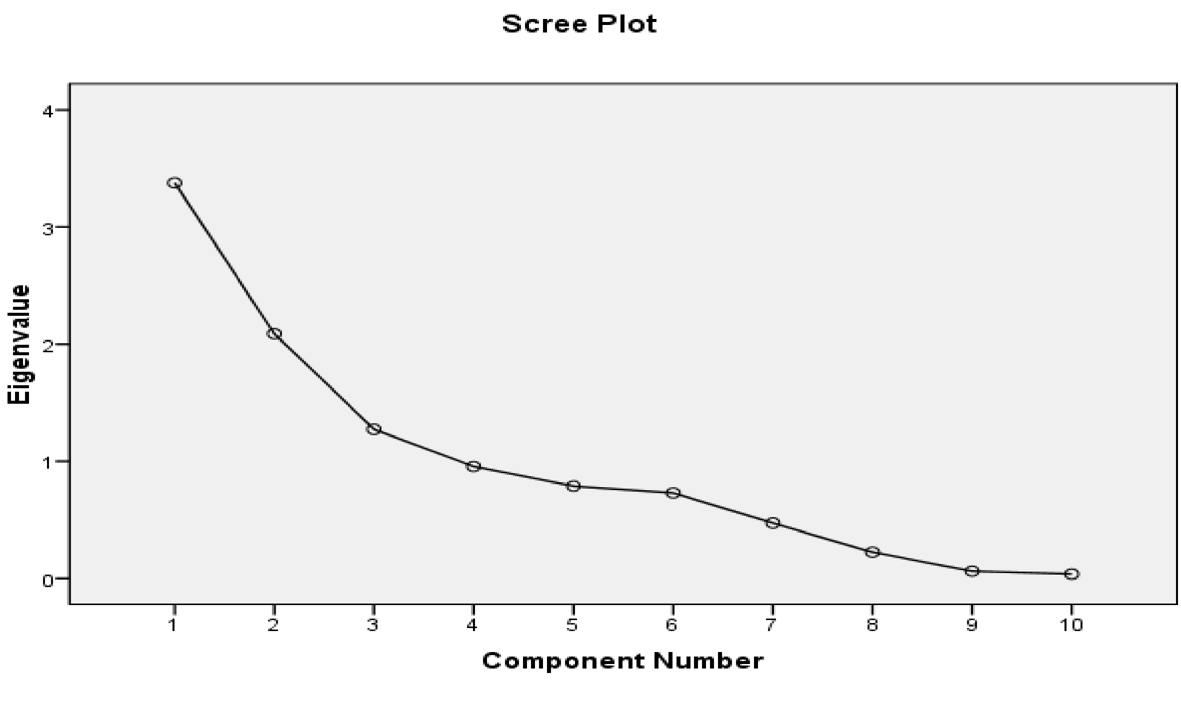

Figure 3: Scree Plot clarify principal components of the variables

From the analysis it is clear thatthere are three principal components to convert variables into a set of values. As shown in (table 5),the first two components (PC1 and PC2) explain 33.76% and 22.88%. The third component comprise 12.72% of the variation and the remaining components explain gradually decreasing contributions (with eigenvalues <1). First three components comprise cumulative 67.36% of the variation.

Table (5): Principal Component Analysis Matrix

Component Matrix			
		Component	
	1	2	3
D.O	-.783	-.196	.034
pH	-.083	.406	-.537
EC	**.868**	.261	-.154
TDS	**.872**	.222	-.123
Temp.	-.210	.386	**.620**
Pb	**.419**	-.123	**.664**
Cu	**.693**	.006	-.101
Cd	-.557	**.702**	-.006
Ni	-.427	-.452	-.328
Zn	.224	-.952	.009

V. CONCLUSION:

Physicochemical parameters of the surface water were mostly deviated from the DoE standard, as there are numerous industrial sectors discharging chemicals from different units. DO,EC, TDS, pH are important indicator of water quality but all of the parameters also do not comply with DoE standard.Since Surface water quality is deteriorated it is no more suitable for potable use. In case of trace elements, except (Pb, Cd, Ni) were higher than standard values. The sources of trace elements are mainly from industrial usages. Pearson correlation matrixis showedsignificant correlations among variables which indicate their possible common sources. There are two main clusters among the variables Cluster 1(EC and TDS) and Cluster 2 (Cu,Cd, Ni, Pb, Zn, DO,pH and Temperature) indicating possible common characteristics or sources. PCA showed three factors to accomplish the sample variable matrix.Most of the sources of elements are assumed industrial sources which use wide variety of chemicals in different processes. Excessive limit of the components have deleterious impact not only on the plants but also on the human being.

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